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(54) **CONTROL VALVE FOR VARIABLE DISPLACEMENT COMPRESSOR**

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(52) **U.S. Cl.** **417/222.2**; 62/228.5; 62/228.3
(58) **Field of Search** 417/222.2; 62/228.5, 62/228.3

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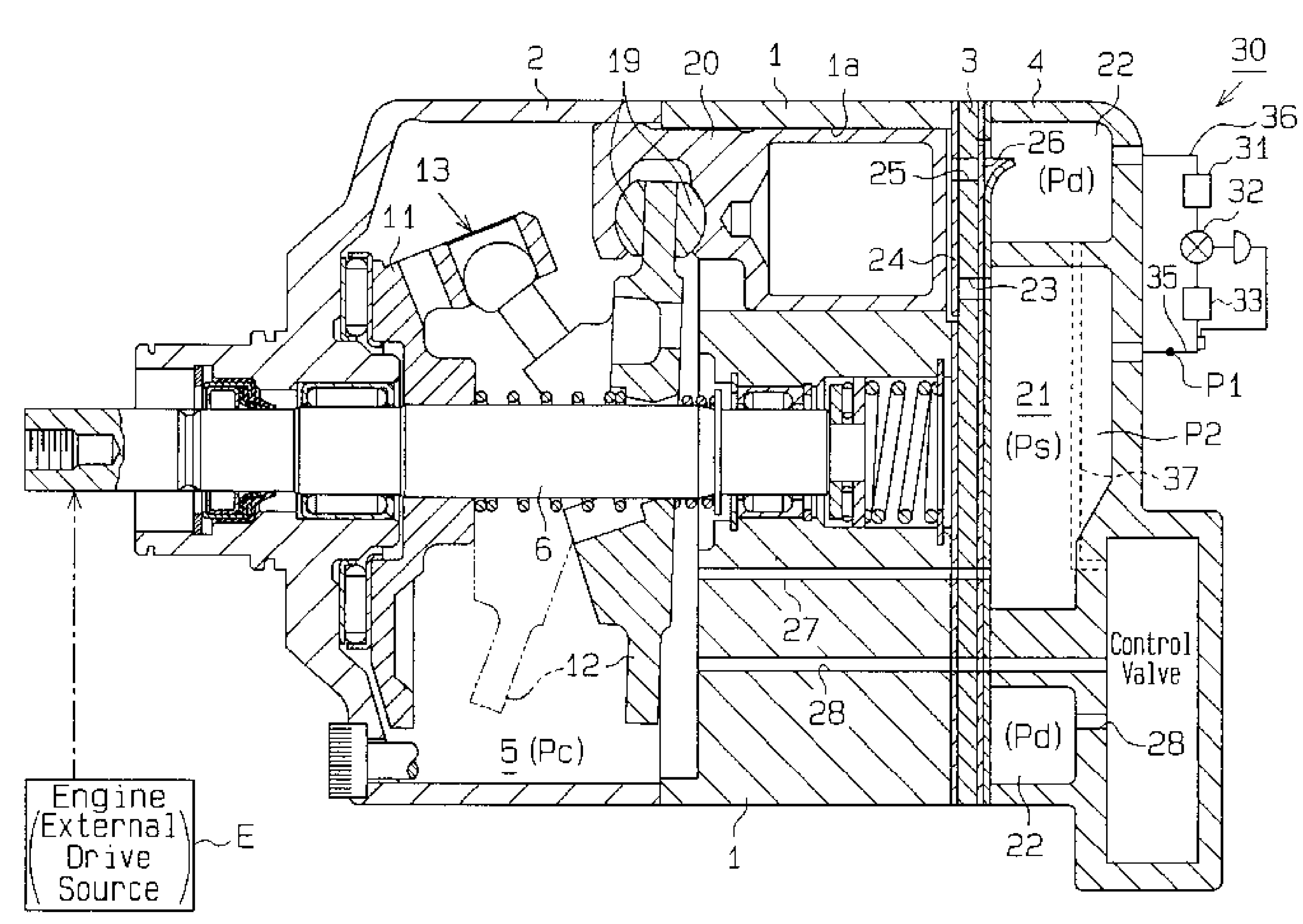
(57) **ABSTRACT**

A control valve has a valve housing. A valve chamber and a pressure sensing chamber are defined in the valve housing, respectively. A pressure sensing member is located in the pressure sensing chamber. A pressure sensing rod is slidably supported by the valve housing. A valve body is accommodated in the valve chamber. An end of the pressure sensing rod is connected to the pressure sensing member and the other end of the pressure sensing rod contacts the valve body. A solenoid chamber is defined in the valve housing. A stationary iron core is located between the valve chamber and the solenoid chamber. A solenoid rod extends through and is slidably supported by the stationary iron core. An urging force applied to the pressure sensing member by an actuator through the solenoid rod corresponds to a target value of the pressure difference. The pressure sensing member moves the valve body such that the pressure difference seeks the target value.

12 Claims, 5 Drawing Sheets



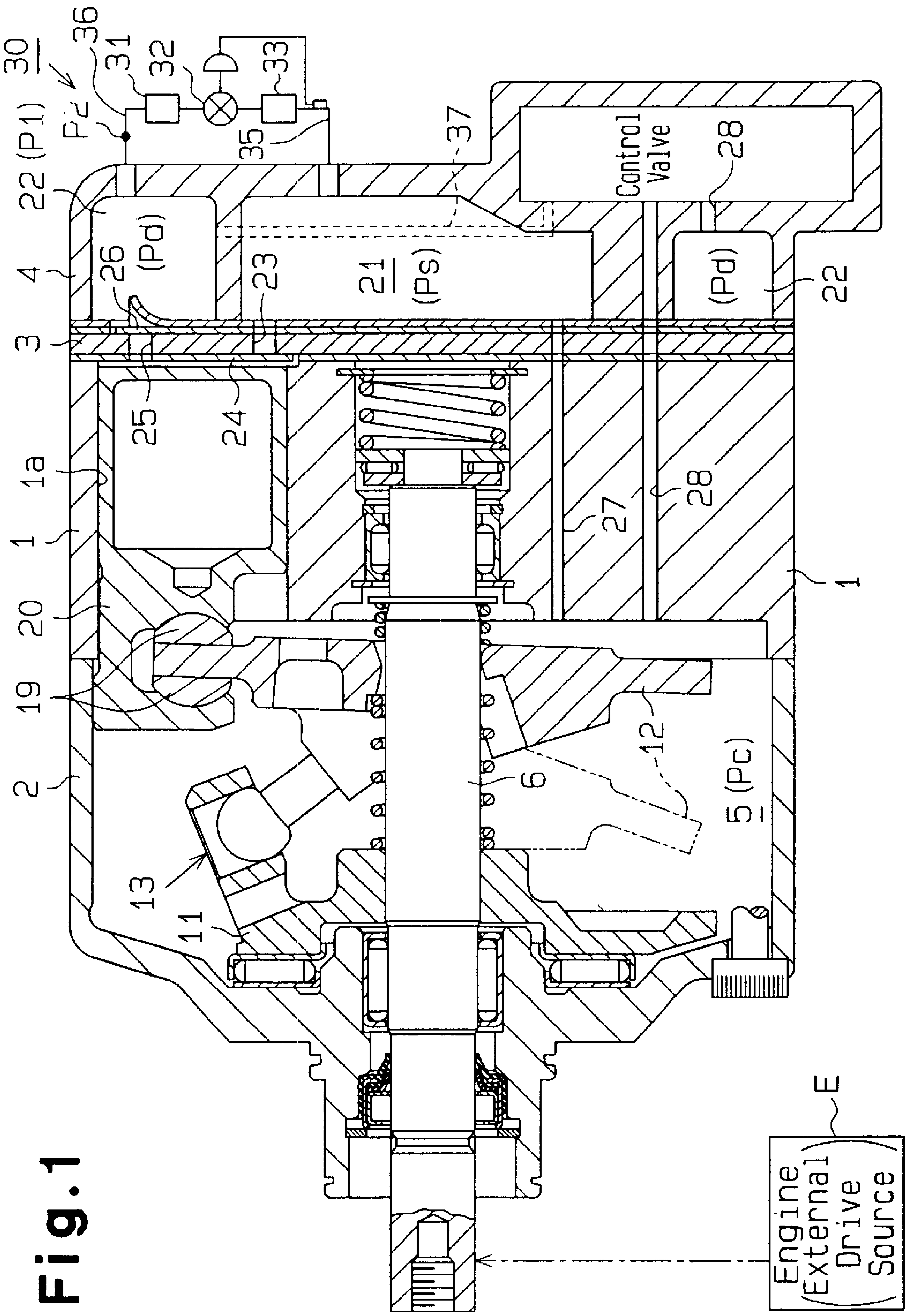

30
36
31
32
33
Pd
22 (P1)
35
37
Control Valve
28
22
(Pd)
4
26
(Pd)
23
21
(Ps)
3
25
24
1a
1
27
28
20
19
2
12
6
5 (Pc)
13
11
E
Engine (External Drive Source)

Fig.1

Fig.2

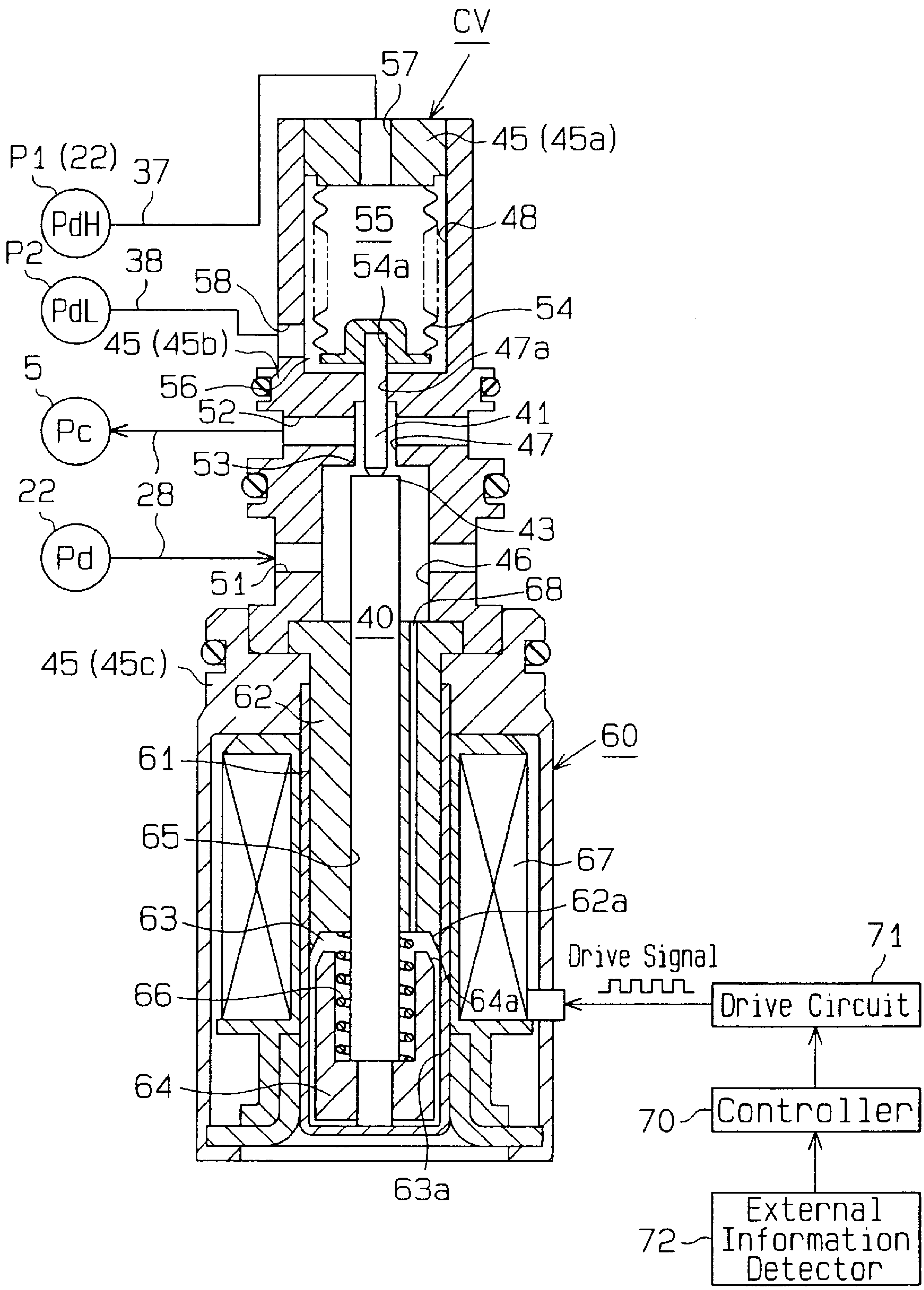
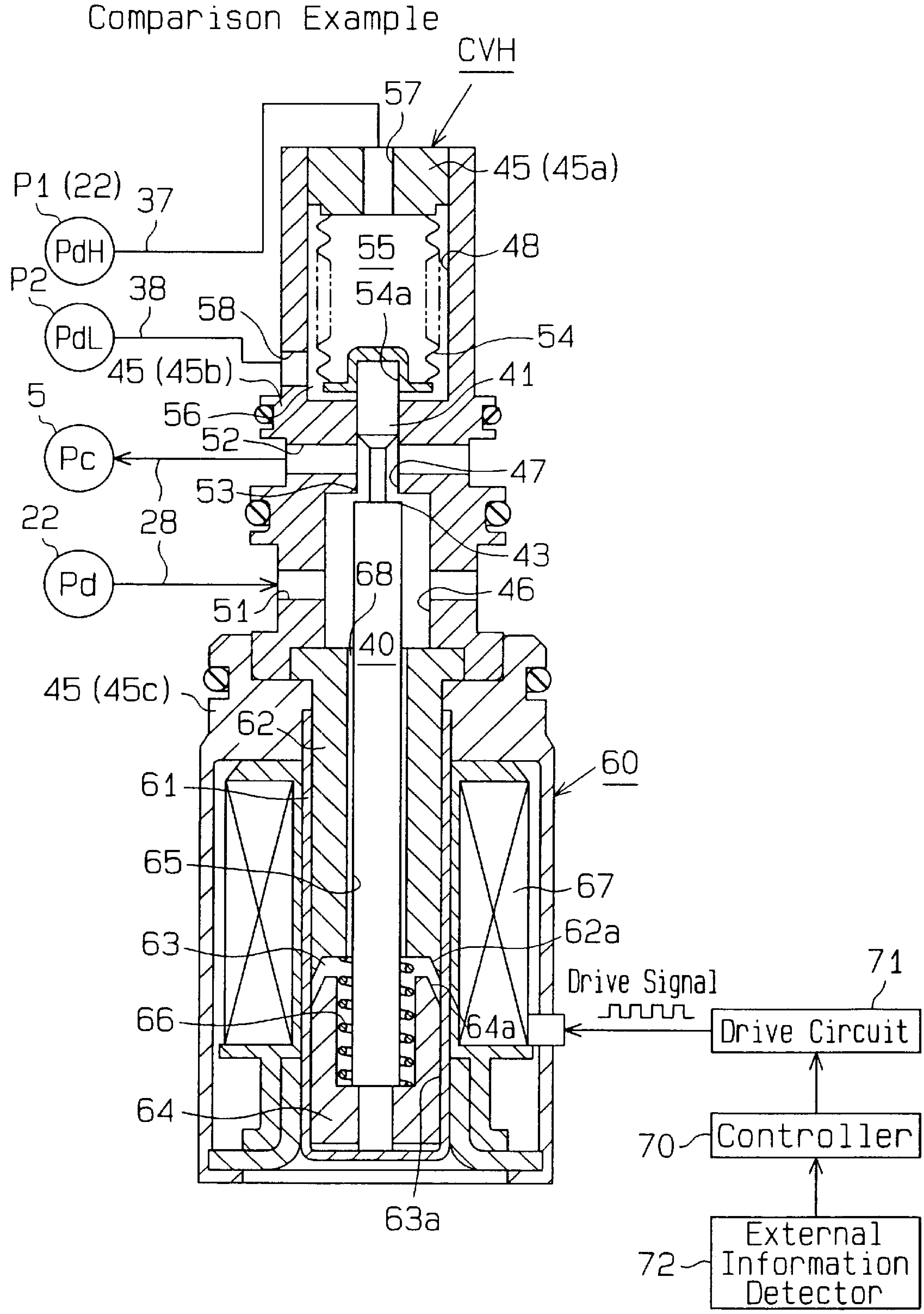

CV
57
45 (45a)
P1 (22)
37
PdH
48
55
54a
P2
38
PdL
58
54
45 (45b)
47a
5
56
52
41
Pc
47
53
43
22
28
Pd
46
51
68
40
45 (45c)
62
60
61
65
67
62a
63
Drive Signal
71
66
64a
Drive Circuit
64
Controller
70
63a
External
Information
Detector
72

Fig.3


Comparison Example
CVH
57
45 (45a)
P1 (22)
37
PdH
55
54a
48
P2
38
PdL
58
54
45 (45b)
41
5
56
52
Pc
47
53
43
22
28
Pd
68
46
51
40
45 (45c)
62
60
61
65
67
63
62a
Drive Signal
71
66
64a
Drive Circuit
64
70
Controller
63a
72
External Information Detector

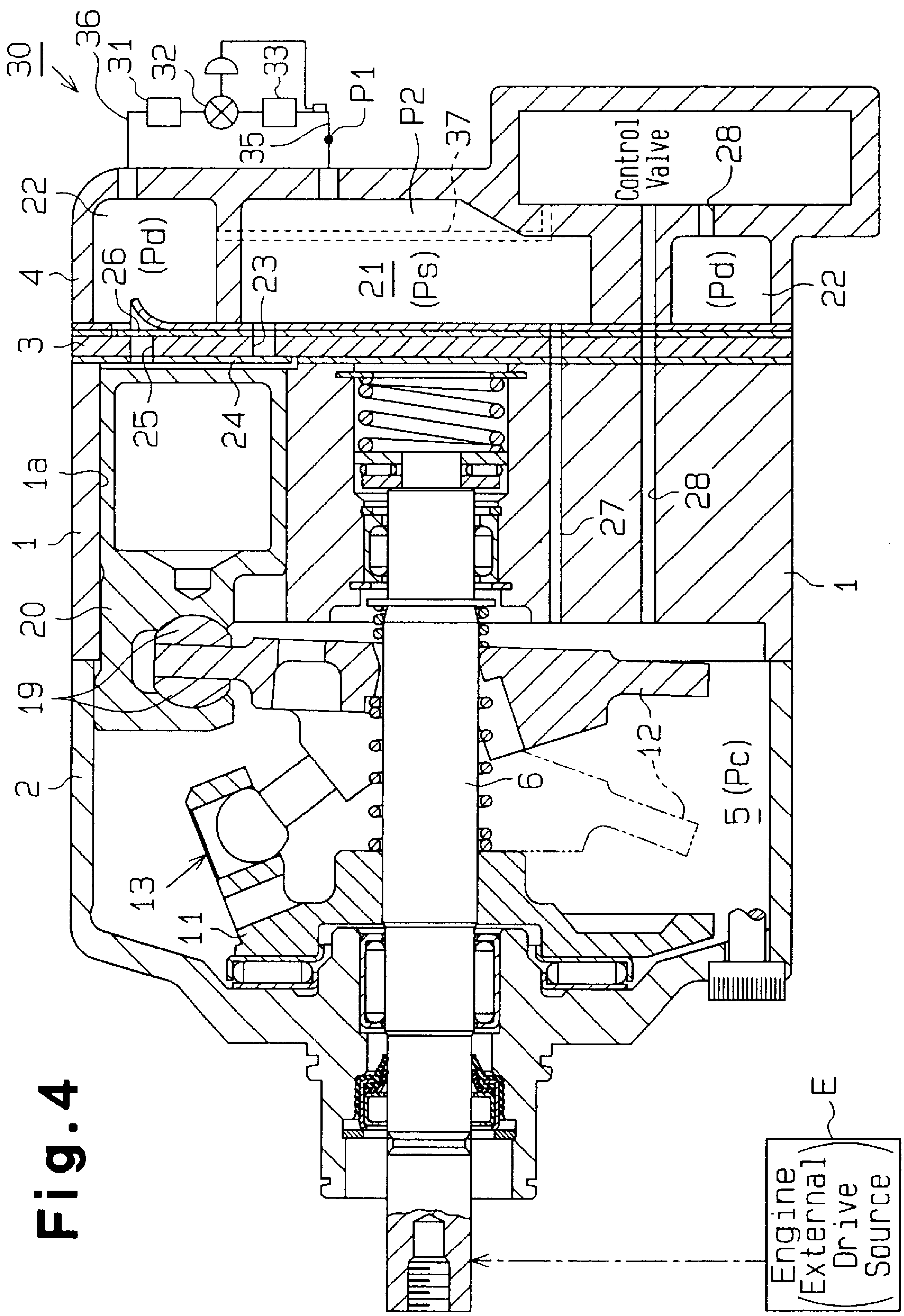
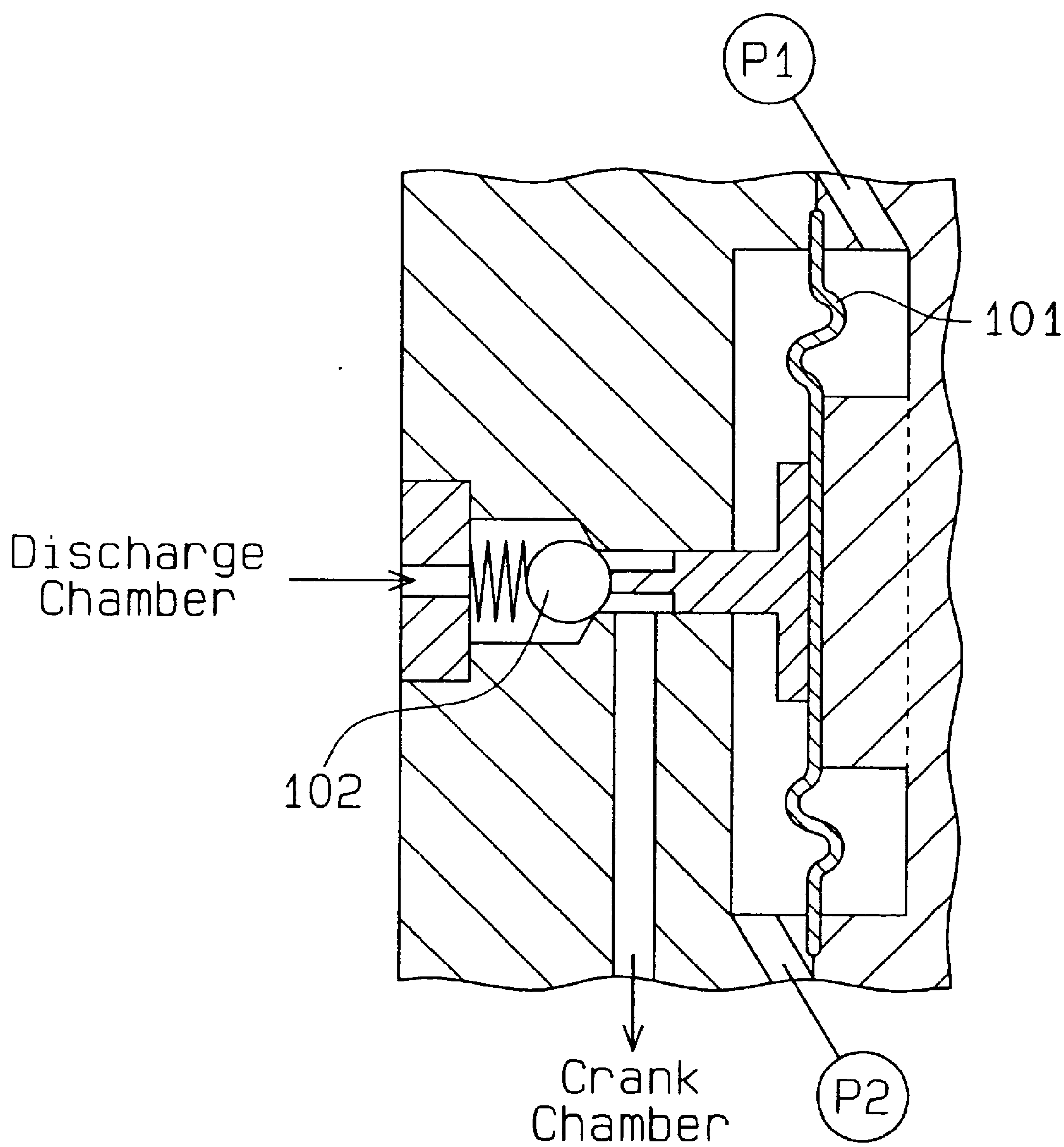

30
36
31
32
33
P1
P2
35
37
Control Valve
28
22
(Pd)
4
26
3
23
21
(Ps)
25
24
1a
1
27
20
19
2
12
6
5 (Pc)
13
11
E
Engine (External Drive Source)

Fig.4

Fig.5 (Prior Art)



CONTROL VALVE FOR VARIABLE DISPLACEMENT COMPRESSOR

BACKGROUND OF THE INVENTION

The present invention relates to a control valve for a variable displacement compressor that is used in a refrigerant circuit of a vehicle air conditioner.

FIG. **5** illustrates a part of a control valve disclosed in Japanese Unexamined Patent Publication No. 11-324930. In this control valve, two pressure monitoring points **P1**, **P2** are located in a refrigerant circuit. The pressure difference between the two points monitoring **P1**, **P2** is mechanically detected by a pressure sensing member **101**. The position of a valve body **102** is determined in accordance with a force generated based on the pressure difference. The pressure in a control chamber (for example, the crank chamber of a swash plate type compressor) is adjusted according to the position of the valve body **102**.

The pressure difference between the pressure monitoring points **P1**, **P2** represents the flow rate of refrigerant in the refrigerant circuit. The pressure sensing member **101** determines the position of the valve body **102** such that the displacement of the compressor is changed to cancel the fluctuation of the pressure difference, or the fluctuation of the refrigerant flow rate in the refrigerant circuit.

The above described control valve has a simple internal self-control function for maintaining a predetermined single refrigerant flow rate. In other words, the control valve does not actively change the refrigerant flow rate, and therefore, cannot respond to subtle changes in demand for controlling the air conditioning.

SUMMARY OF THE INVENTION

Accordingly, it is an objective of the present invention to provide a control valve for a variable displacement compressor that accurately controls air conditioning.

To achieve the foregoing and other objectives and in accordance with the purpose of the present invention, a control valve used for a variable displacement compressor installed in a refrigerant circuit is provided. The compressor varies the displacement in accordance with the pressure in a control chamber. The compressor has a control passage, which connects the control chamber to a pressure zone in which the pressure is different from the pressure of the control chamber. The control valve includes a valve housing, a valve chamber defined in the valve housing, a valve body, a pressure sensing chamber defined in the valve housing, a pressure sensing member, a pressure sensing rod, a solenoid chamber, a movable iron core, a stationary iron core, a solenoid rod, and an electromagnetic actuator. The valve body is accommodated in the valve chamber for adjusting the opening degree of the control passage. The pressure sensing member divides the pressure sensing chamber into a first pressure chamber and a second pressure chamber. The pressure at a first pressure monitoring point in the refrigerant circuit is applied to the first pressure chamber. The pressure at a second pressure monitoring point in the refrigerant circuit, which is downstream of the first pressure monitoring point, is applied to the second pressure chamber. The pressure sensing rod is slidably supported by the valve housing between the valve chamber and the pressure sensing chamber. An end of the pressure sensing rod is connected to the pressure sensing member and the other end of the pressure sensing rod contacts the valve body. The pressure sensing member moves the valve body via the pressure sensing rod

in accordance with the pressure difference between the first pressure chamber and the second pressure chamber such that the displacement of the compressor is varied to counter changes of the pressure difference. The solenoid chamber is defined in the valve housing to be adjacent to the valve chamber. The movable iron core is movably accommodated in the solenoid chamber. The stationary iron core is located between the valve chamber and the solenoid chamber. The stationary iron core separates the valve chamber from the solenoid chamber. The solenoid rod extends through and is slidably supported by the stationary iron core. The solenoid rod supports the valve body in the valve chamber and supports the movable iron core in the solenoid chamber. The electromagnetic actuator applies an urging force to the pressure sensing member in accordance with an external command. The electromagnetic actuator includes the movable iron core and the stationary iron core. The urging force applied to the pressure sensing member by the actuator corresponds to a target value of the pressure difference. The pressure sensing member moves the valve body such that the pressure difference seeks the target value.

Other aspects and advantages of the invention will become apparent from the following description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention, together with objects and advantages thereof, may best be understood by reference to the following description of the presently preferred embodiments together with the accompanying drawings in which:

FIG. **1** is a cross-sectional view illustrating a swash plate type variable displacement compressor according to a first embodiment of the present invention;

FIG. **2** is a cross-sectional view illustrating the control valve used in the compressor shown in FIG. **1**;

FIG. **3** is a cross-sectional view illustrating a control valve of a comparison example;

FIG. **4** is a cross-sectional view illustrating a compressor according to a second embodiment of the present invention; and

FIG. **5** is a cross-sectional view illustrating a prior art control valve.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A control valve according to a first embodiment of the present invention will now be described with reference to FIGS. **1** to **3**. The control valve is used in a variable displacement swash plate type compressor located in a vehicle air conditioner.

As shown in FIG. **1**, the compressor includes a cylinder block **1**, a front housing member **2** connected to the front end of the cylinder block **1**, and a rear housing member **4** connected to the rear end of the cylinder block **1**. A valve plate assembly **3** is located between the rear housing member **4** and the cylinder block **1**. The cylinder block **1**, the front housing member **2**, and the rear housing member **4** form the housing of the compressor.

A control chamber, which is a crank chamber **5** in this embodiment, is defined between the cylinder block **1** and the front housing member **2**. A drive shaft **6** extends through the crank chamber **5** and is rotatably supported. The drive shaft **6** is connected to and driven by an external drive source, which is an engine E in this embodiment.

A lug plate **11** is fixed to the drive shaft **6** in the crank chamber **5** to rotate integrally with the drive shaft **6**. A drive plate, which is a swash plate **12** in this embodiment, is accommodated in the crank chamber **5**. The swash plate **12** slides along the drive shaft **6** and inclines with respect to the axis of the drive shaft **6**. A hinge mechanism **13** is provided between the lug plate **11** and the swash plate **12**. The hinge mechanism **13** and the lug plate **11** cause the swash plate **12** to move integrally with the drive shaft **6**.

Cylinder bores **1***a* (only one is shown in FIG. **1**) are formed in the cylinder block **1** at constant angular intervals around the axis L of the drive shaft **6**. Each cylinder bore **1***a* accommodates a single headed piston **20** such that the piston **20** can reciprocate in the cylinder bore **1***a*. The opening of each cylinder bore **1***a* is closed by the valve plate assembly **3** and the corresponding piston **20**. A compression chamber, the volume of which varies in accordance with the reciprocation of the piston **20**, is defined in each cylinder bore **1***a*. The front end of each piston **20** is coupled to the periphery of the swash plate **12** through a pair of shoes **19**. The swash plate **12** is rotated as the drive shaft **6** rotates. Rotation of the swash plate **12** is converted into reciprocation of each piston **20** by the corresponding pair of shoes **19**.

A suction chamber **21** and a discharge chamber **22** are defined between the valve plate assembly **3** and the rear housing member **4**. The discharge chamber **22** is located about the suction chamber **21**. The valve plate assembly **3** has suction ports **23**, suction valve flaps **24**, discharge ports **25**, and discharge valve flaps **26**. Each set of a suction port **23**, a suction valve flap **24**, a discharge port **25**, and a discharge valve flap **26** corresponds to one of the cylinder bores **1***a*.

When each piston **20** moves from the top dead center position to the bottom dead center position, refrigerant gas in the suction chamber **21** flows into the corresponding cylinder bore **1***a* via the corresponding suction port **23** and suction valve flap **24**. When each piston **20** moves from the bottom dead center position to the top dead center position, refrigerant gas in the corresponding cylinder bore **1***a* is compressed to a predetermined pressure and is discharged to the discharge chamber **22** via the corresponding discharge port **25** and discharge valve flap **26**.

A mechanism for controlling the pressure in the crank chamber **5**, or crank chamber pressure Pc, includes a bleed passage **27**, a supply passage **28**, and the control valve CV. The passages **27**, **28** are formed in the housing. The bleed passage **27** connects a suction pressure zone Ps, or the suction chamber **21**, with the crank chamber **5**. The supply passage **28** connects a discharge pressure zone Pd, or the discharge chamber **22**, with the crank chamber **5**. The control valve CV is located in the supply passage **28**.

The control valve CV changes the opening of the supply passage **28** to adjust the flow rate of refrigerant gas from the discharge chamber **22** to the crank chamber **5**. The crank chamber pressure Pc is changed in accordance with the relationship between the flow rate of refrigerant gas flowing from the discharge chamber **22** to the crank chamber **5** and the flow rate of refrigerant gas flowing out from the crank chamber **5** to the suction chamber **21** through the bleed passage **27**. The difference between the crank chamber pressure Pc and the pressure in the cylinder bores **1***a* is changed in accordance with the crank chamber pressure Pc, which varies the inclination angle of the swash plate **12**. This alters the stroke of each piston **20** and the compressor displacement.

The refrigerant circuit of the vehicular air-conditioner is made up of the compressor and an external refrigerant circuit **30**. The external refrigerant circuit **30** connects the discharge chamber **22** to the suction chamber **21**, and includes a condenser **31**, an expansion valve **32**, and an evaporator **33**. A downstream pipe **35** is located in a downstream portion of the external refrigerant circuit **30**. The downstream pipe **35** connects the outlet of the evaporator **33** with the suction chamber **21** of the compressor. An upstream pipe **36** is located in the upstream portion of the external refrigerant circuit **30**. The upstream pipe **36** connects the discharge chamber **22** of the compressor with the inlet of the condenser **31**.

The greater the flow rate of the refrigerant flowing in the refrigerant circuit is, the greater the pressure loss per unit length of the circuit or piping is. That is, the pressure loss (pressure difference) between pressure monitoring points P1, P2 has a positive correlation with the flow rate of the refrigerant in the circuit. Detecting the pressure difference between the pressure monitoring points P1, P2 permits the flow rate of refrigerant in the refrigerant circuit to be indirectly detected. Hereinafter, the pressure difference between the pressure monitoring points P1, P2 will be referred to as pressure difference ΔPd.

As shown in FIG. **2**, the first pressure monitoring point P1 is located in the discharge chamber **22**, the pressure of which is equal to that of the most upstream section of the upstream pipe **36**. The second pressure monitoring point P2 is set midway along the upstream pipe **36** at a position separated from the first pressure monitoring point P1 by a predetermined distance. The pressure PdH at the first pressure monitoring point P1 is applied to the displacement control valve CV through a first pressure introduction passage **37**. The pressure PdL at the second pressure monitoring point P2 is applied to the displacement control valve CV through a second pressure introduction passage **38**.

The control valve CV has a supply control valve portion and a solenoid **60**. The supply control valve portion controls the opening (throttle amount) of the supply passage **28**, which connects the discharge chamber **22** with the crank chamber **5**. The solenoid **60** serves as an electromagnetic actuator for controlling a solenoid rod **40** located in the control valve CV on the basis of an externally supplied electric current. The solenoid rod **40** has a valve body **43** at the distal end.

A valve housing **45** of the control valve CV has a plug **45***a*, an upper half body **45***b*, and a lower half body **45***c*. A valve chamber **46** and a communication passage **47** are defined in the upper half body **45***b*. A pressure sensing chamber **48** is defined between the upper half body **45***b* and the plug **45***a*.

The solenoid rod **40** moves in the axial direction of the control valve CV in the valve chamber **46**. The valve chamber **46** is selectively connected to and disconnected from the communication passage **47** in accordance with the position of the solenoid rod **40**. A pressure sensing rod **41**, which is separated from the solenoid rod **40**, is located in the communication passage **47**. The pressure sensing rod **41** moves in the axial direction of the control valve CV and is fitted in a small diameter portion **47***a* of the communication passage **47**. The rod pressure sensing rod **41** disconnects the communication passage **47** from the pressure sensing chamber **48**.

The upper end face of a stationary iron core **62**, which will be discussed below, serves as the bottom wall of the valve chamber **46**. A first valve port **51**, extending radially from the valve chamber **46**, connects the valve chamber **46** with the discharge chamber **22** through an upstream part of the supply passage **28**. A second valve port **52**, extending radially from the communication passage **47**, connects the communication passage **47** with the crank chamber **5** through a downstream part of the supply passage **28**. Thus, the first valve port **51**, the valve chamber **46**, the communication passage **47**, and the second valve port **52** serve as part of the control passage, or the supply passage **28**, which connects the discharge chamber **22** with the crank chamber **5**.

The valve body portion **43** of the solenoid rod **40** is located in the valve chamber **46**. The step between the valve chamber **46** and the communication passage **47** functions as a valve seat **53**. When the solenoid rod **40** moves from the position of FIG. **2** (the lowest position) to the highest position, at which the valve body portion **43** contacts the valve seat **53**, the communication passage **47** is isolated. That is, the valve body portion **43** functions as a valve body that selectively opens and closes the supply passage **28**.

A pressure sensing member, which is a bellows **54** in this embodiment, is located in the pressure sensing chamber **48**. The upper end of the bellows **54** is fixed to the plug **45***a* of the valve housing **45**. The pressure sensing chamber **48** is divided into a first pressure chamber **55** and a second pressure chamber **56** by the bellows **54**.

A rod seat **54***a* is located at the lower end of the bellows **54**. The upper end of the pressure sensing rod **41** is located in the rod seat **54***a*. The bellows **54** is installed in an elastically deformed state. The bellows **54** urges the pressure sensing rod **41** downward through the rod seat **54***a* by the downward force generated by the elastic deformation. Therefore, the lower end of the pressure sensing rod **41** is pressed against the upper end of the solenoid rod **40** by the force of the bellows **54**. The pressure sensing rod **41** moves integrally with the solenoid rod **40**.

The first pressure chamber **55** is connected to the first pressure monitoring point **P1**, which is the discharge chamber **22**, through a **P1** port **57** formed in the plug **45***a*, and the first pressure introduction passage **37**. The second pressure chamber **56** is connected to the second pressure monitoring point **P2** through a **P2** port **58**, which is formed in the upper half body **45***b* of the valve housing **45**, and the second pressure introduction passage **38**. Therefore, the first pressure chamber **55** is exposed to the pressure PdH monitored at the first pressure monitoring point **P1**, and the second pressure chamber **56** is exposed to the pressure PdL monitored at the second pressure monitoring point **P2**.

The solenoid **60** includes an accommodating cup **61**. The stationary iron core **62** is fitted in the upper part of the accommodating cup **61**. A solenoid chamber **63** is defined in the accommodating cup **61**. A movable iron core **64** is accommodated in the solenoid chamber **63** to move along the axis of the valve housing **45**. The movable iron core **64** is formed like a cylindrical column. The outer diameter of the movable iron core **64** is smaller than the diameter of the inner surface **63***a* of the solenoid chamber **63** (the accommodating cup **61**).

An axially extending guide hole **65** is formed in the central portion of the stationary iron core **62**. The solenoid rod **40** is located to move axially in the guide hole **65**. The lower end of the solenoid rod **40** is secured to the movable iron core **64** in the solenoid chamber **63**. Therefore, the movable iron core **64** is supported by the guide hole **65** (the stationary iron core **62**) through the solenoid rod **40**, and moves integrally with the solenoid rod **40**. That is, displacement of the movable iron core **64** is guided by the guide hole **65** (the stationary iron core **62**) through the solenoid rod **40**.

An annular projection **62***a* having an inclined surface is formed at an end portion (the bottom) of the stationary iron core **62** about the axis of the valve housing **45**. An annular chamfer **64***a* is formed at the upper end of the movable iron core **64** to form a peripheral portion of the movable iron core that faces the inclined surface. The shape of the chamfer **64***a* is determined to match the inner surface of the annular projection **62***a*. This structure permits electromagnetic attraction force generated between the stationary iron core **62** and the movable iron core **64** to be accurately controlled according to the distance between the cores **62** and **64**. The electromagnetic force will be discussed later.

A pressure passage **68** is formed in the stationary iron core **62** for connecting the valve chamber **46** with the solenoid chamber **63**. The solenoid chamber **63** is exposed to the discharge pressure Pd of the valve chamber **46** through the pressure passage **68**. In the solenoid chamber **63**, spaces at the axial sides of the movable iron core **64** are exposed to the discharge pressure Pd through the clearance between the inner surface **63***a* of the solenoid chamber **63** and the movable iron core **64**. Although not discussed in detail, exposing the solenoid chamber **63** to the discharge pressure Pd permits the position of the solenoid rod **40**, or the opening degree of the control valve CV, to be accurately controlled.

In the solenoid chamber **63**, a coil spring **66** is located between the stationary iron core **62** and the movable iron core **64**. The spring **66** urges the movable iron core **64** downward, or away from the stationary iron core **62**.

A coil **67** is wound about the stationary iron core **62** and the movable iron core **64**. The coil **67** is connected to a drive circuit **71**, and the drive circuit **71** is connected to a controller **70**. The controller **70** is connected to an external information detector **72**. The controller **70** receives external information (on-off state of the air conditioner, the temperature of the passenger compartment, and a target temperature) from the detector **72**. Based on the received information, the controller **70** commands the drive circuit **71** to supply a drive signal to the coil **67**. The coil **67** generates an electromagnetic force, the magnitude of which depends on the value of the supplied current, between the stationary iron core **62** and the movable iron core **64**. The value of the current supplied to the coil **67** is controlled by controlling the voltage applied to the coil **67**. In this embodiment, the applied voltage is controlled by pulse-width modulation.

The opening degree of the control valve CV is determined by the position of the solenoid rod **40**.

When no current is supplied to the coil **67** (duty ratio=0%), the downward force of the bellows **54** and the spring **66** is dominant in determining the position of the solenoid rod **40**. As a result, the solenoid rod **40** is moved to its lowermost position shown in FIG. **2** and causes the valve body **43** to fully open the communication passage **47**. Accordingly, the crank chamber pressure Pc is maximized. Therefore, the difference between the crank chamber pressure Pc and the pressure in the cylinder bores **1***a* is increased, which minimizes the inclination angle of the swash plate **12** and the compressor displacement.

When the electric current corresponding to the minimum duty ratio (duty ratio>0%) within the range of duty ratios is supplied to the coil **67**, the upward electromagnetic force exceeds the downward force of the bellows **54** and the spring **66**, and the solenoid rod **40** moves upward. In this state, the resultant of the upward electromagnetic force and the downward force of the spring **66** acts against the resultant of the forces of the bellows **54** and the force based on the pressure difference between the pressure monitoring points **P1**, **P2**

($\Delta Pd=PdH-PdL$). The position of the valve body **43** of the solenoid rod **40** relative to the valve seat **53** is determined such that upward and downward forces are balanced.

When the speed of the engine E is lowered, the flow rate in the refrigerant circuit is decreased. At this time, the downward force based on the pressure difference ΔPd is decreased and the solenoid rod **40** (the valve body **43**) moves upward, which decreases the opening of the communication passage **47**. The crank chamber pressure Pc is decreased accordingly. This increases the inclination angle of the swash plate **12** and the compressor displacement. When the compressor displacement is increased, the pressure difference ΔPd is increased.

When the speed of the engine E is increased, the flow rate in the refrigerant circuit is increased. At this time, the downward force based on the pressure difference ΔPd is increased and the solenoid rod **40** (the valve body **43**) moves downward, which increases the opening of the communication passage **47**. The crank chamber pressure Pc is increased accordingly. This decreases the inclination angle of the swash plate **12** and the compressor displacement. When the compressor displacement is decreased, the flow rate in the refrigerant circuit is decreased and the pressure difference ΔPd is decreased.

If the duty ratio to the coil **67** is increased to increase the upward electromagnetic force, the solenoid rod **40** moves upward and the opening degree of the communication passage **47** is decreased. As a result, the compressor displacement is increased, the flow rate in the refrigerant circuit is increased and the pressure difference ΔPd is increased.

If the duty ratio to the coil **67** is decreased to decrease the upward electromagnetic force, the solenoid rod **40** moves downward and the opening degree of the communication passage **47** is increased. As a result, the compressor displacement is decreased, the flow rate in the refrigerant circuit is decreased and the pressure difference ΔPd is decreased.

As described above, the target value of the pressure difference ΔPd is determined by the duty ratio supplied to the coil **67**. The control valve CV automatically determines the position of the solenoid rod **40** according to changes of the pressure difference ΔPd to maintain the pressure difference ΔPd to the target value. The target value of the pressure difference ΔPd is changed by adjusting the duty ratio to the coil **67**.

The embodiment of FIGS. **1** and **2** has the following advantages.

The pressure difference ΔPd that is a reference for adjusting the opening degree of the control valve CV is changed by changing the duty ratio supplied to the coil **67**. Therefore, the control valve CV can perform more delicate control compared with a control valve that has no electromagnetic actuator (solenoid **60**), and has only a single target pressure difference.

FIG. **3** shows a control valve CVH of a comparison example. The example control valve CVH is the same as the control valve CV except for the following three points. First, the pressure sensing rod **41** is fixed to the solenoid rod **40**. Second, the pressure passage **68** is replaced by the clearance between the guide hole **65** and the solenoid rod **40**. Lastly, the diameter of the inner surface **63***a* of the solenoid chamber **63** is substantially equal to the outer diameter of the movable iron core **64**, and the movable iron core **64** is slidably supported by the inner surface **63***a*. That is, the pressure sensing rod **41**, the solenoid rod **40**, and the movable iron core **64** are slidably supported by the valve housing **45** at the contacting parts of the pressure sensing rod **41** and the communication passage **47**, and at the contacting parts of the movable iron core **64** and the inner surface **63***a* of the solenoid chamber **63**.

As described above, the solenoid rod **40**, the pressure sensing rod **41**, and the movable iron core **64** form an integral member, which is supported at two locations in the valve housing **45**. Improving the machining accuracy of one of the supported portions, or eliminating chattering, prevents errors at the other supported portion from being absorbed. Therefore, assembly of the integral member to the valve housing **45** is difficult.

Consequently, the machining accuracy at the supported portions cannot be sufficiently improved. This significantly displaces the axis of the stationary iron core **62** from the axis of the movable iron core **64**. Accordingly, the space between the cores **62**, **64** is reduced at one side. In this state, the electromagnetic force acts to move the movable iron core **64** radially such that the already reduced space is further reduced. In other words, the movable iron core **64** is moved in a direction perpendicular to its axis. This increases the friction at the supported portions, and creates hysteresis in the control valve CVH.

In contrast with the control valve CVH, the solenoid rod **40** (the valve body **43** and the pressure sensing rod **41**) of the control valve CV is separately formed from the pressure sensing rod **41**. Therefore, the solenoid rod **40** (the valve body **43**) may be moved relative to each other in directions perpendicular to the axis of the valve housing **45**. Therefore, even if electromagnetic force between the movable iron core **64** and the stationary iron core **62** moves the solenoid rod **40** in a direction perpendicular to the axis of the valve housing **45**, the movement of the solenoid rod **40** is not transmitted to the pressure sensing rod **41**. This decreases the friction acting on the pressure sensing rod **41**. As a result, hysteresis is prevented in the control valve CV.

The movable iron core **64** of the control valve CV is moved integrally with the solenoid rod **40**, which slides along the guide hole **65** formed in the stationary iron core **62**. That is, the integral member having the solenoid rod **40** and the movable iron core **64** is supported at one location, or at the guide hole **65**. Therefore, improving the machining accuracy of the guide hole **65** and the solenoid rod **40** does not cause the assembly of the integral member to the housing **45** to be difficult. As a result, the position of the movable iron core **64** is accurately determined while the axis of the movable iron core **64** is aligned with the axis of the stationary iron core **62**. Therefore, lateral force applied to the solenoid rod **40** is reduced. As a result, hysteresis of the control valve CV is further reduced.

It should be apparent to those skilled in the art that the present invention may be embodied in many other specific forms without departing from the spirit or scope of the invention. Particularly, it should be understood that the invention may be embodied in the following forms.

FIG. **4** illustrates a second embodiment of the present invention. The second embodiment is a modification of the first embodiment. In the second embodiment, the first pressure monitoring point P1 is located in the suction pressure zone Ps, which includes the evaporator **33** and the suction chamber **21**. Specifically, the first pressure monitoring point P1 is located in the downstream pipe **35**. The second pressure monitoring point P2 is also located in the suction pressure zone Ps and downstream of the first pressure monitoring point P1. Specifically, the second pressure monitoring point P2 is located in the suction chamber **21**.

The first pressure monitoring point P1 may be located in the discharge pressure zone Pd, which includes the discharge chamber **22** and the condenser **31**, and the second pressure monitoring point P2 may be located in the suction pressure zone Ps, which includes the evaporator **33** and the suction chamber **21**.

The first pressure monitoring point P1 may be located in the discharge pressure zone Pd, which includes the discharge chamber **22** and the condenser **31**, and the second pressure monitoring point P2 may be located in the crank chamber **5**.

In the pressure sensing chamber **48** shown in FIG. **2**, the interior of the bellows **54** may function as the second pressure chamber **56**, and the space outside of the bellows **54** may function as the first pressure chamber **55**. In this case, the first pressure monitoring point P1 is located in the crank chamber **5**, and the second pressure monitoring point P2 is located in the suction pressure zone Ps, which includes the evaporator **33** and the suction chamber **21**.

The locations of the pressure monitoring points P1 and P2 are not limited to the main circuit of the refrigerant circuit, which includes the evaporator **33**, the suction chamber **21**, the cylinder bores **1***a*, the discharge chamber **22**, and the condenser **31**. That is, the pressure monitoring points P1 and P2 need not be in a high pressure zone or a low pressure zone of the refrigerant circuit. For example, the pressure monitoring points P1, P2 may be located in the crank chamber **5**, which is an intermediate pressure zone of a refrigerant passage for controlling the compressor displacement. The displacement controlling passage is a sub-circuit of the refrigerant circuit, and includes the supply passage **28**, the crank chamber **5**, and the bleed passage **27**.

In the control valve CV shown in FIG. **2**, the valve chamber **46** may be connected to the crank chamber **5** through a downstream section of the supply passage **28**, and the communication passage **47** may be connected to the discharge chamber **22** through an upstream section of the supply passage **28**. In this case, the pressure difference between the second pressure chamber **56** and the communication passage **47**, which is adjacent to the second pressure chamber **56**, is decreased. This prevents refrigerant from leaking between the communication passage **47** and the second pressure chamber **56** and thus permits the compressor displacement to be accurately controlled.

The control valve CV may be used as a bleed control valve for controlling the crank chamber pressure Pc by controlling the opening of the bleed passage **27**.

The present invention may be embodied in a control valve of a wobble type variable displacement compressor.

In the illustrated embodiments of FIGS. **1** to **4**, the swash plate **12** may be coupled to a fluid pressure actuator. In this case, the high pressure section of the bleed passage **27** and the low pressure section of the supply passage **28** are connected to a pressure chamber of the actuator. The control valve CV controls the pressure in the pressure chamber of the actuator thereby changing the inclination angle of the swash plate **12**.

Therefore, the present examples and embodiments are to be considered as illustrative and not restrictive and the invention is not to be limited to the details given herein, but may be modified within the scope and equivalence of the appended claims.

What is claimed is:

1. A control valve used for a variable displacement compressor installed in a refrigerant circuit, wherein the compressor has a discharge pressure zone, a suction pressure zone, and a crank pressure zone, wherein the compressor varies the displacement in accordance with the pressure in a control chamber, wherein the compressor has a control passage, which connects the control chamber to a pressure zone in which the pressure is different from the pressure of the control chamber, the control valve comprising:

a valve housing;

a valve chamber defined in the valve housing;

a valve body, which is accommodated in the valve chamber for adjusting the opening degree of the control passage;

a pressure sensing chamber defined in the valve housing;

a pressure sensing member, which divides the pressure sensing chamber into a first pressure chamber and a second pressure chamber, wherein the pressure at a first pressure monitoring point in any one of the discharge pressure zone, the suction pressure zone, and the crank pressure zone is applied to the first pressure chamber, wherein the pressure at a second pressure monitoring point in any one of the discharge pressure zone, the suction pressure zone, and the crank pressure zone, which is downstream of the first pressure monitoring point, is applied to the second pressure chamber;

a pressure sensing rod slidably supported by the valve housing between the valve chamber and the pressure sensing chamber, wherein an end of the pressure sensing rod is connected to the pressure sensing member and the other end of the pressure sensing rod contacts the valve body, wherein the pressure sensing member moves the valve body via the pressure sensing rod in accordance with the pressure difference between the first pressure chamber and the second pressure chamber such that the displacement of the compressor is varied to counter changes of the pressure difference;

a solenoid chamber defined in the valve housing to be adjacent to the valve chamber;

a movable iron core movably accommodated in the solenoid chamber;

a stationary iron core located between the valve chamber and the solenoid chamber, wherein the stationary iron core separates the valve chamber from the solenoid chamber;

a solenoid rod, which extends through and is slidably supported by the stationary iron core, wherein the solenoid rod supports the valve body in the valve chamber and supports the movable iron core in the solenoid chamber; and

an electromagnetic actuator for applying an urging force to the pressure sensing member in accordance with an external command, wherein the electromagnetic actuator includes the movable iron core and the stationary iron core, wherein the urging force applied to the pressure sensing member by the actuator corresponds to a target value of the pressure difference, and wherein the pressure sensing member moves the valve body such that the pressure difference seeks the target value.

2. The control valve according to claim **1**, wherein the movable iron core is guided only by the stationary iron core via the solenoid rod.

3. The control valve according to claim **1**, wherein the first and second pressure monitoring points are located in the discharge pressure zone.

4. The control valve according to claim **3**, wherein the control passage is a supply passage, which connects the control chamber to the discharge pressure zone, wherein the valve chamber forms a part of the supply passage, wherein the control valve has a communication passage, the opening degree of which is adjusted by the valve body, and wherein the valve chamber is connected to the discharge pressure zone via the communication passage.

5. The control valve according to claim **1**, wherein the first and second pressure monitoring points are located in the suction pressure zone.

6. The control valve according to claim **1**, wherein an inclined surface is formed on an end portion of the stationary iron core, wherein the inclined surface is inclined with respect to an axis of the stationary iron core, wherein a peripheral portion of the movable iron core faces the inclined surface, and wherein the peripheral portion as chamfered to match the inclined surface.

7. A control valve used for a variable displacement compressor installed in a refrigerant circuit of an air conditioner, wherein the compressor has a discharge pressure zone, a suction pressure zone, and a crank pressure zone, wherein the compressor varies the displacement in accordance with the pressure in a control chamber, wherein the compressor has a control passage, which connects the control chamber to a pressure zone in which the pressure is different from the pressure of the control chamber, the control valve comprising:

a valve housing;

a valve chamber defined in the valve housing;

a valve body, which is accommodated in the valve chamber for adjusting the opening degree of the control passage;

a pressure sensing chamber defined in the valve housing;

a pressure sensing member, which divides the pressure sensing chamber into a first pressure chamber and a second pressure chamber, wherein the pressure at a first pressure monitoring point in any one of the discharge pressure zone, the suction pressure zone, and the crank pressure zone is applied to the first pressure chamber, wherein the pressure at a second pressure monitoring point in any one of the discharge pressure zone, the suction pressure zone, and the crank pressure zone, which is downstream of the first pressure monitoring point, is applied to the second pressure chamber;

a pressure sensing rod slidably supported by the valve housing between the valve chamber and the pressure sensing chamber, wherein an end of the pressure sensing rod is connected to the pressure sensing member and the other end of the pressure sensing rod contacts the valve body, wherein the pressure sensing member moves the valve body via the pressure sensing rod in accordance with the pressure difference between the first pressure chamber and the second pressure chamber such that the displacement of the compressor is varied to counter changes of the pressure difference;

a solenoid chamber defined in the valve housing to be adjacent to the valve chamber;

a movable iron core movably accommodated in the solenoid chamber;

a stationary iron core located between the valve chamber and the solenoid chamber, wherein the stationary iron core separates the valve chamber from the solenoid chamber;

a solenoid rod, which extends through and is slidably supported by the stationary iron core, wherein the solenoid rod supports the valve body in the valve chamber and supports the movable iron core in the solenoid chamber, wherein the solenoid rod moves relative to the pressure sensing rod in directions perpendicular to an axis of the valve housing; and

an electromagnetic actuator for applying an urging force to the solenoid rod to move the pressure sensing member in accordance with an external command, wherein the electromagnetic actuator includes the movable iron core and the stationary iron core, wherein the urging force applied to the pressure sensing member through the solenoid rod by the actuator corresponds to a target value of the pressure difference, and wherein the pressure sensing member moves the valve body such that the pressure difference seeks the target value.

8. The control valve according to claim **7**, wherein the movable iron core is guided only by the stationary iron core via the solenoid rod.

9. The control valve according to claim **7**, wherein the first and second pressure monitoring points are located in the discharge pressure zone.

10. The control valve according to claim **9**, wherein the control passage is a supply passage, which connects the control chamber to the discharge pressure zone, wherein the valve chamber forms a part of the supply passage, wherein the control valve has a communication passage, the opening degree of which is adjusted by the valve body, and wherein the valve chamber is connected to the discharge pressure zone via the communication passage.

11. The control valve according to claim **7**, wherein the first and second pressure monitoring points are located in the suction pressure zone.

12. The control valve according to claim **7**, wherein an inclined surface is formed on an end portion of the stationary iron core, wherein the inclined surface is inclined with respect to an axis of the stationary iron core, wherein a peripheral portion of the movable iron core faces to the inclined surface, and wherein the peripheral portion is chamfered to match the inclined surface.

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